Large Area Microchannel Cooling Using Laminate Constructions

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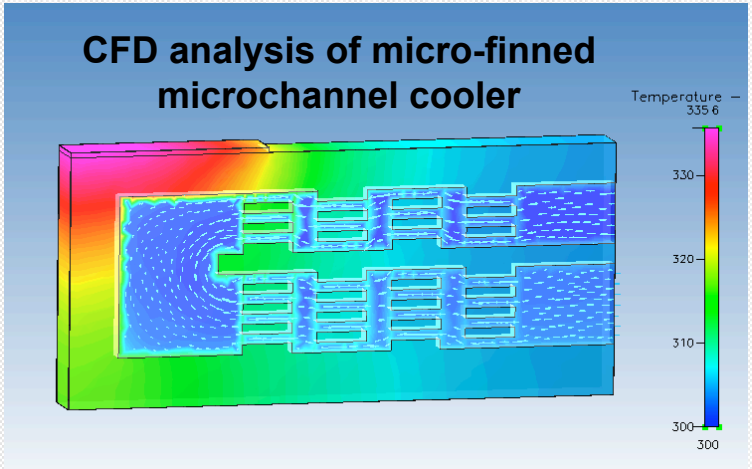
microVection & Micro Cooling Concepts

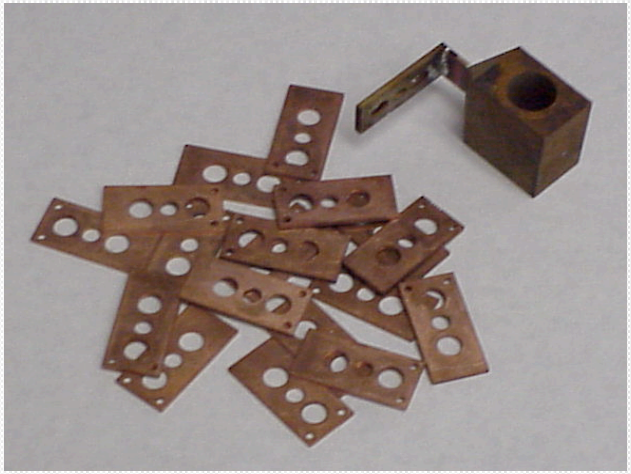
microVection, Inc.

- Research & Development
- Thermal Analysis
- Fluid Analysis
- Experimentation



MICRO COOLING CONCEPTS

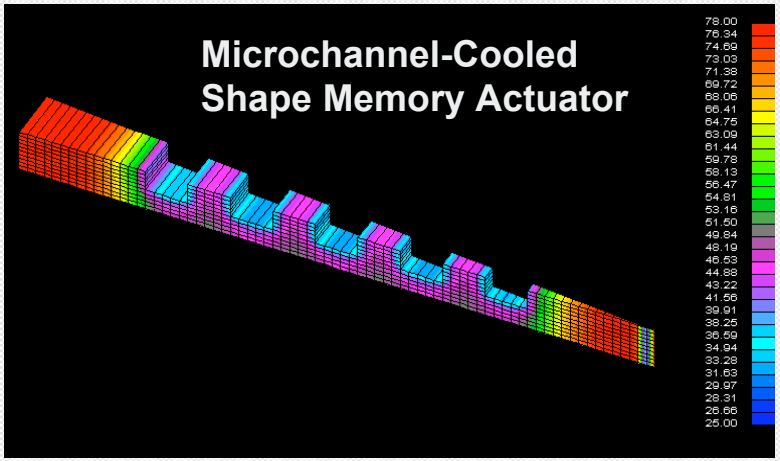
- Comm. Cooler Sales
- Mechanical Design
- Fabrication
- Experimentation

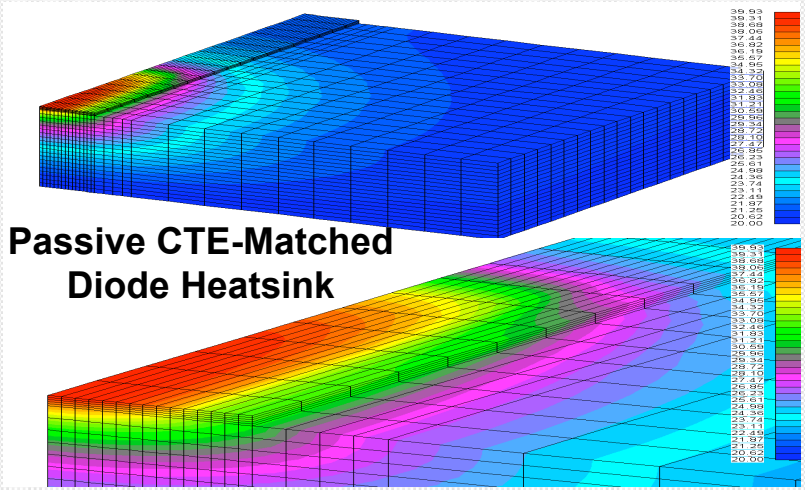


Prototype micro-finned microchannel coolers

microVection, Inc.

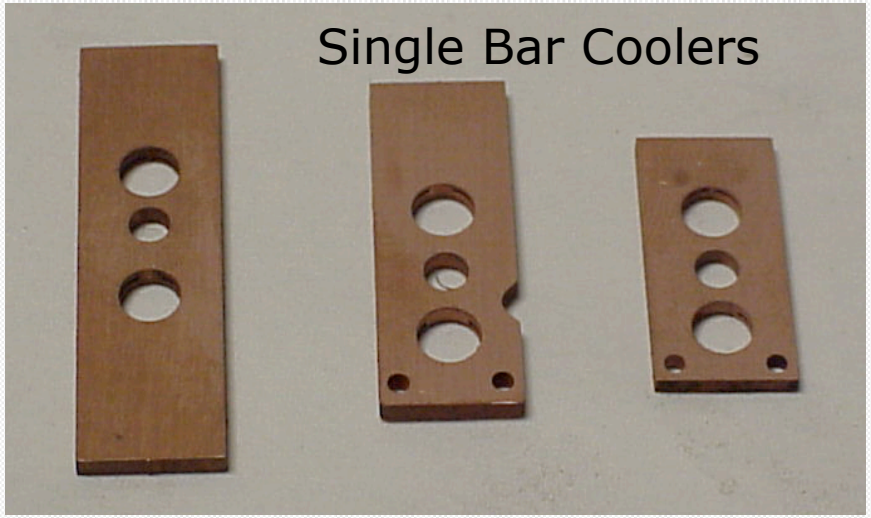
- Small R&D business formed in 2001
  - Focused on development of advanced heat transfer technologies
  - 3 employees, 1000 ft^2 facility
  - More than 15 years' experience in microchannel cooling systems

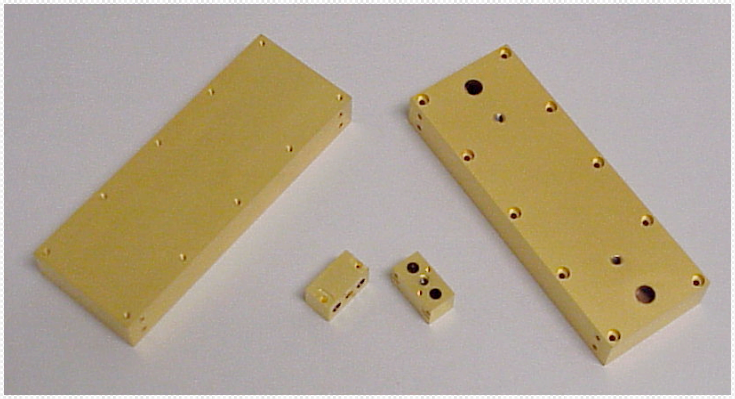


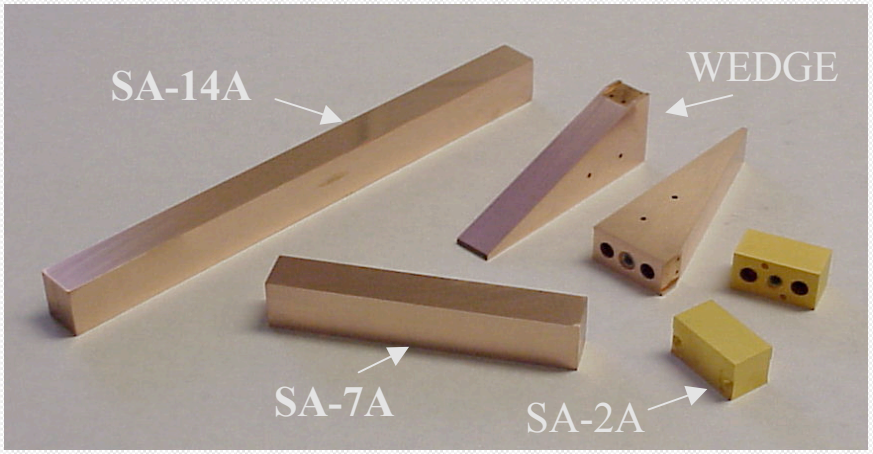


Micro Cooling Concepts (MC^2)

- Microchannel Cooler Fabrication Business Founded in 2000
  - 3 Employees
  - 1700 ft^2 Facility
- MC^2 Has Manufactured & Sold More Than 7000 Microchannel Coolers
  - Laser Diodes & Diode Arrays
  - Aerospace Systems



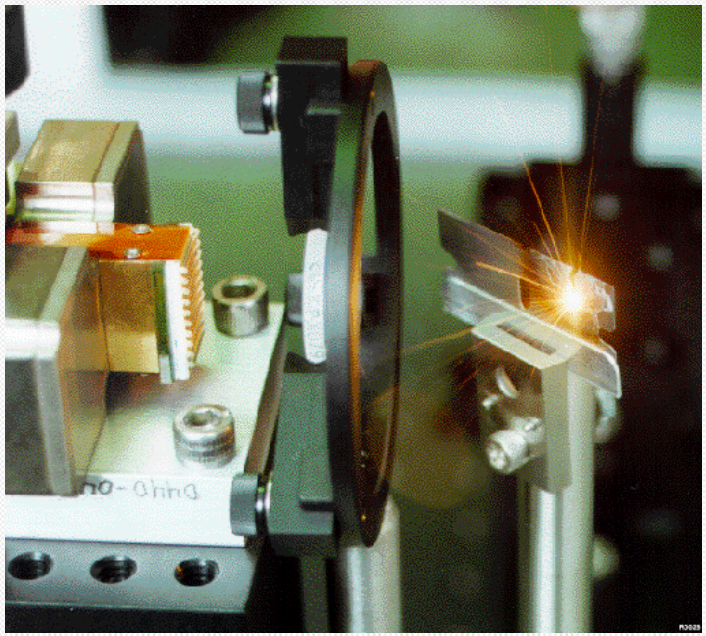




Diode Array Coolers

Microchannel Technology Status

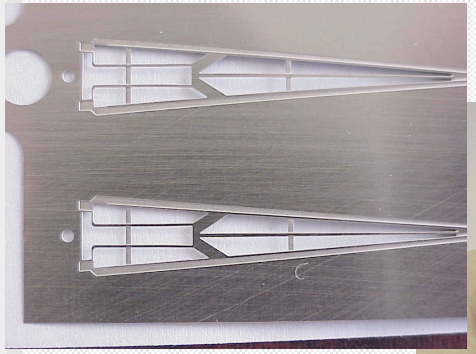
- Single-phase simple microchannels are a mature, commercially successful technology
  - Thousands of coolers built and sold
  - Materials: Cu, Ni, Stainless Steel, Inconel, Waspaloy, Cu/W, Cu/Moly, Kovar
  - Coolants: Water, Aqueous Mixtures, FC-72, LOX, JP-7, N_2, He
  - Channel widths of 12.5 - 250 _m
  - Tested at heat fluxes up to 2.2 kW/cm^2
  - 10 < Re < 3000



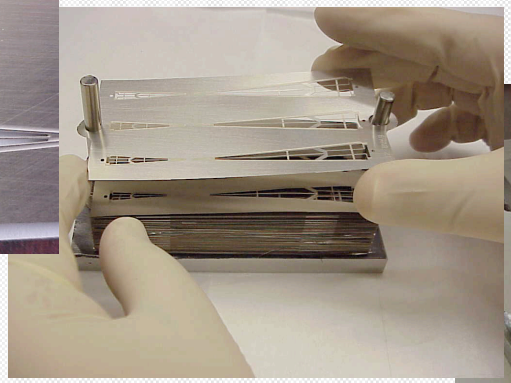
Laminated Foil Fabrication Process

This process has been used to create microchannel cooling passages in a variety of components

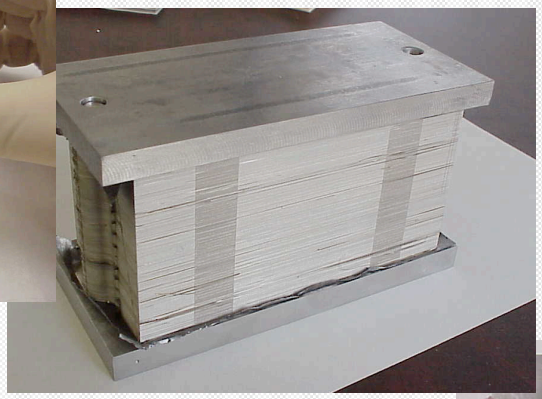
Etch Foils



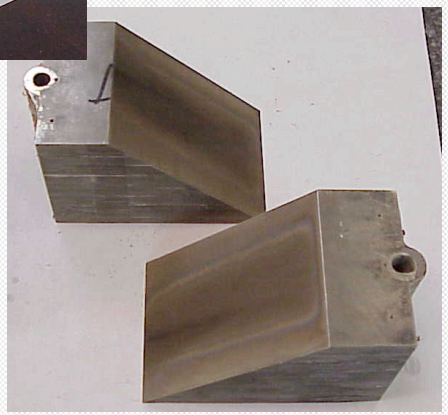
Stack Foils



Bond Stack

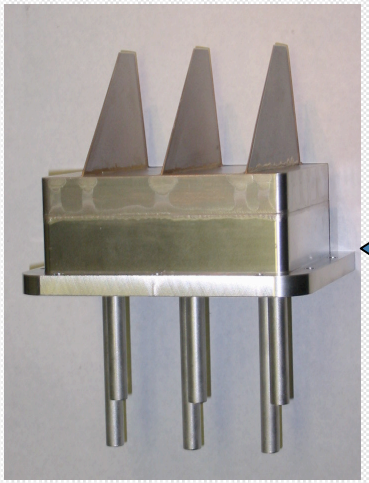


1st Machining Operation



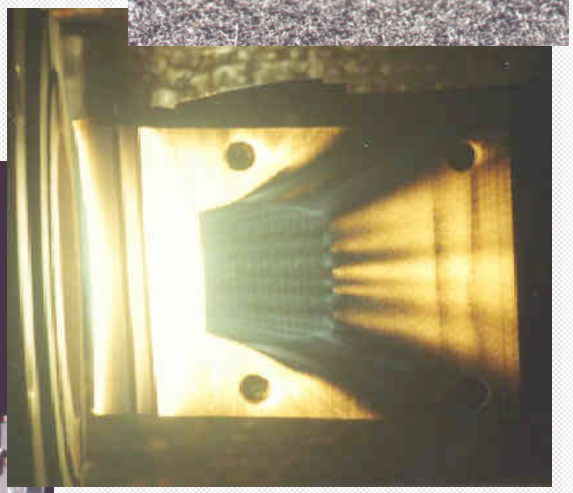
Final Machining

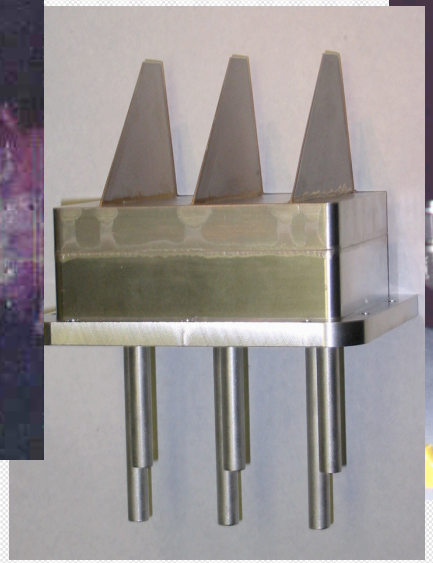
Braze into Flow Fixture



High Heat Flux Applications of Laminate Foil Technology

- Transpiration-Cooled
  - Transpiration Cooled Nosetips
  - Film-Cooled Leading Edges
  - Cooled Antennas and Antenna Windows
- Microchannel-Cooled
  - Leading Edges for Hypersonic Vehicles
  - Scramjet Engine Fuel Injection Struts
  - Rocket Engine Combustors





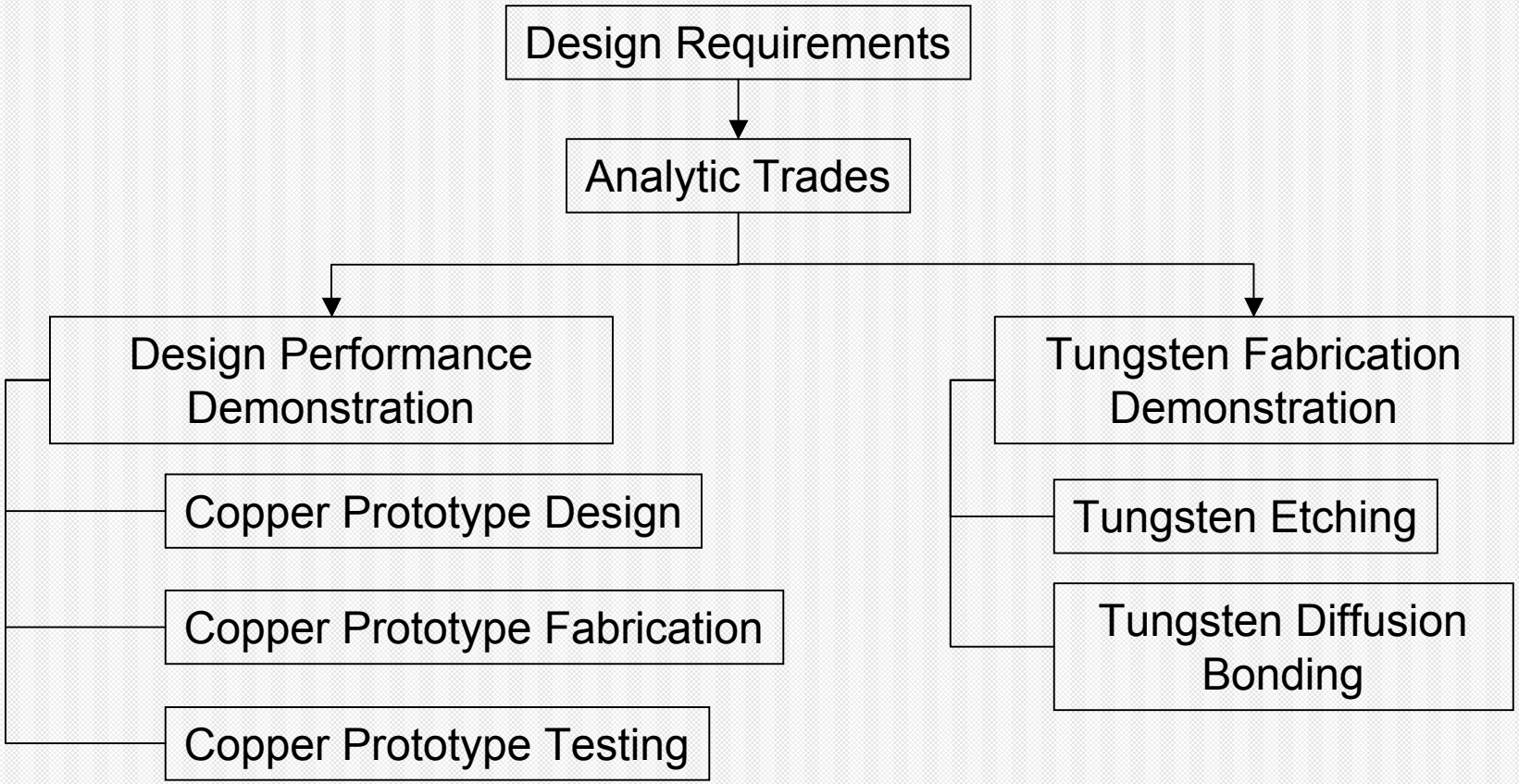
Economical Fabrication of Large Micro-Impingement Cooling Panels

- Phase I SBIR Contract with Saddleback Aerospace
- Grant #DE-FG03-99ER82874
- Contract Duration: 9/4/99 - 3/4/00

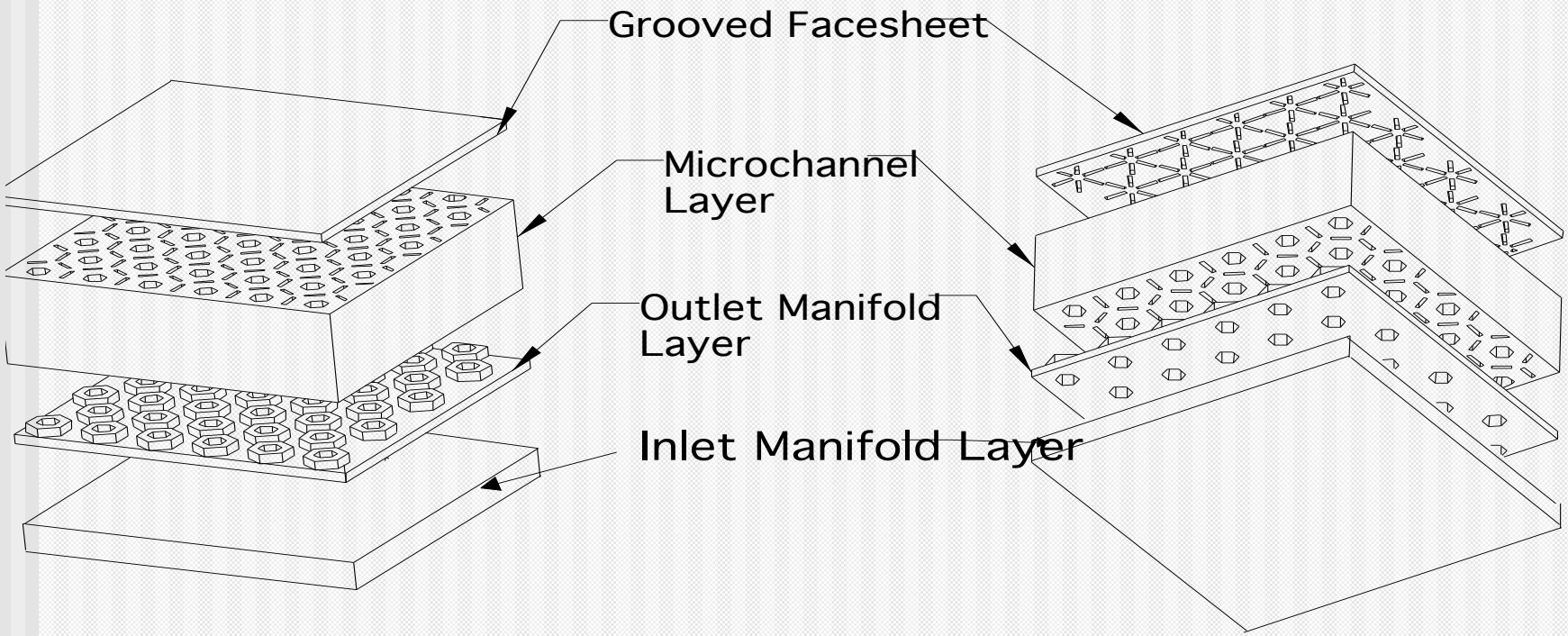
Program Objective and Requirements

- Objective:
  - Development practical, affordable means of applying microchannel cooling over large areas
  - Show that diverter requirements can be met with a tungsten armor/helium coolant system
- Requirements
  - 30 MW/m^2 incident heat flux
  - 0.75 mm tungsten armor
  - Inlet He @ 800^{o}C and 4 MPa

Economical Fabrication of Large Micro-Impingement Cooling Panels (Phase I SBIR)

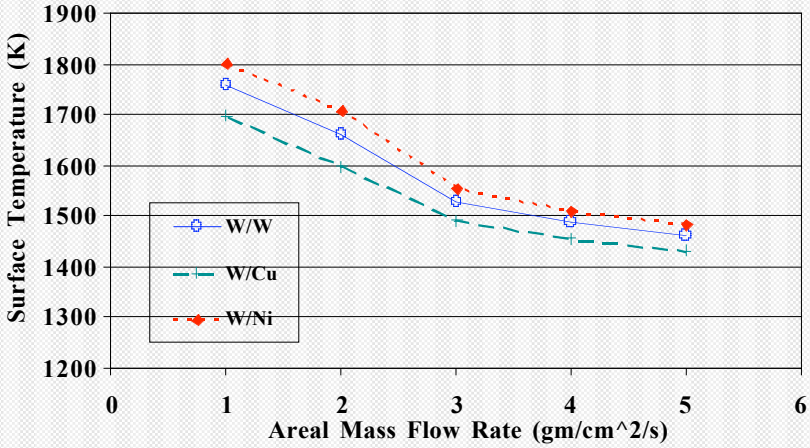


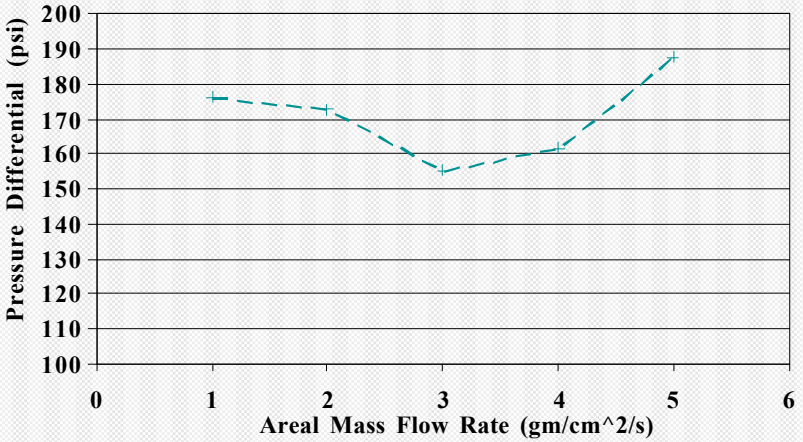
Hexagonal Array Microchannel Concept



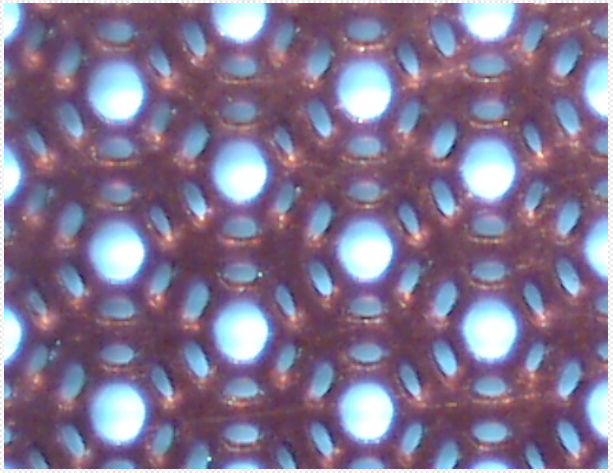
Analytic Performance Trades

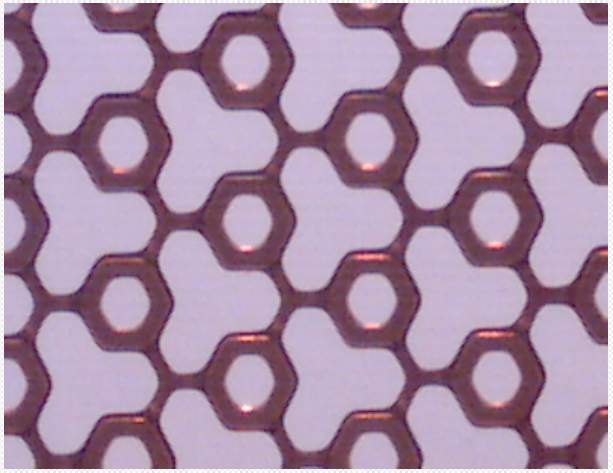
- Compared 3 material systems
  - Copper / Tungsten
  - Nickel / Tungsten
  - Tungsten / Tungsten
- Used 1D compressible flow model to evaluate pressure drop & heat transfer through the system
- Results showed that for thin armors, surface temperatures could be maintained well below melt

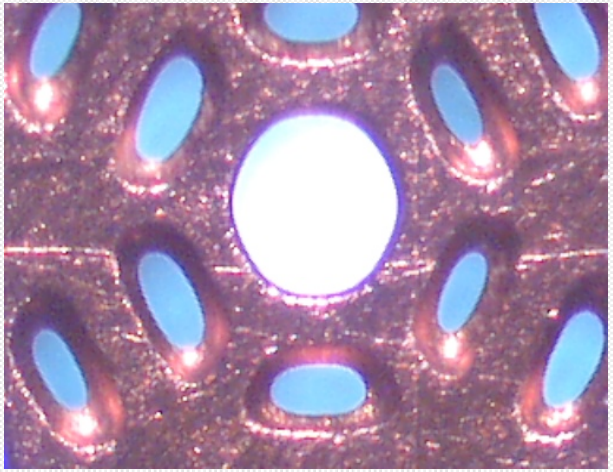


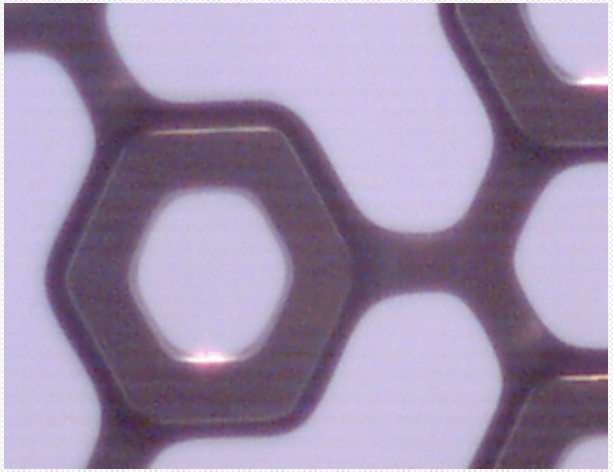


Etched Foils for Phase I Prototype

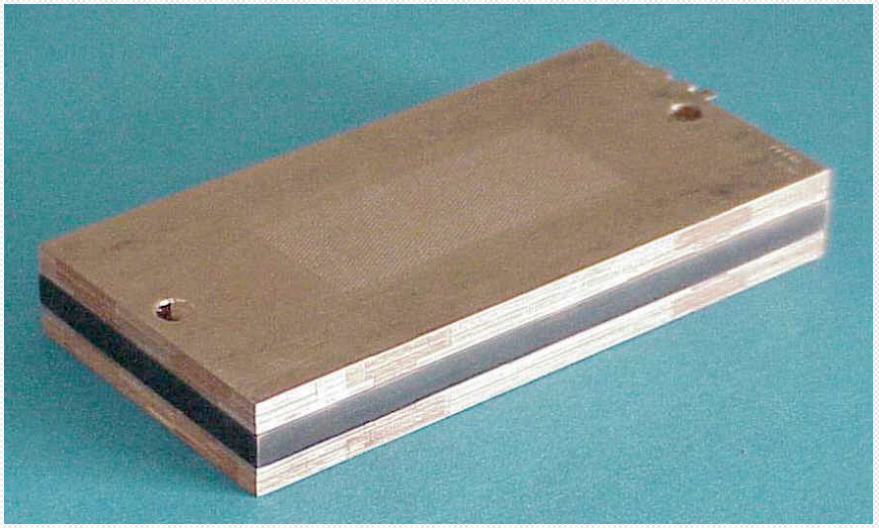




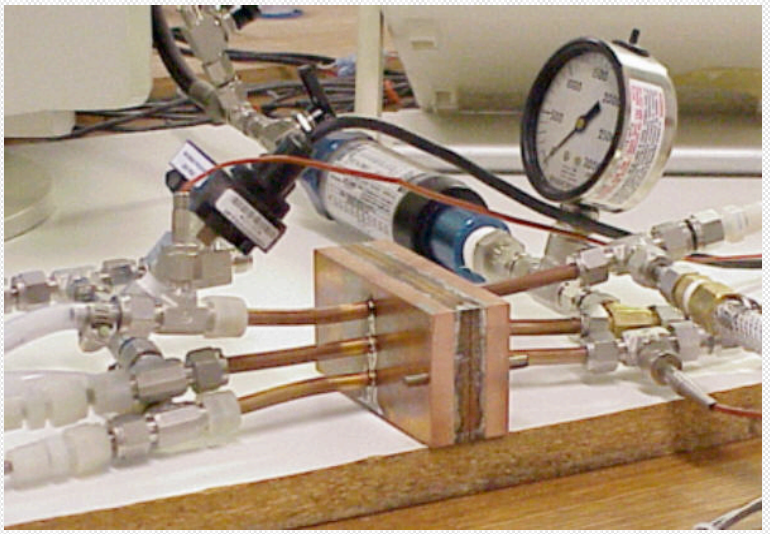




Fabrication and Testing of Glidcop Prototype



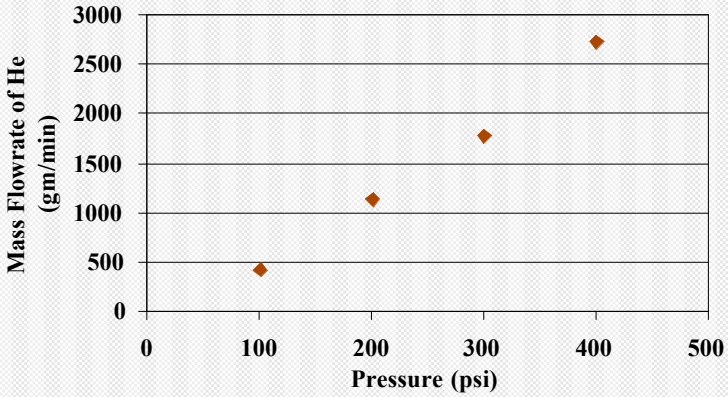
Prototype after diffusion bonding

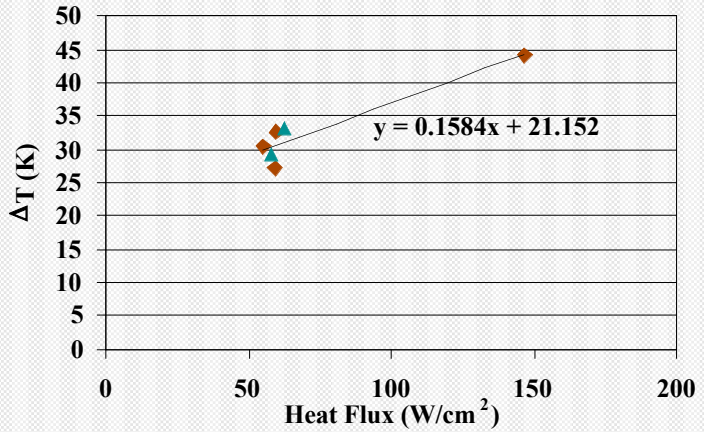


Prototype in test fixture

Test Results

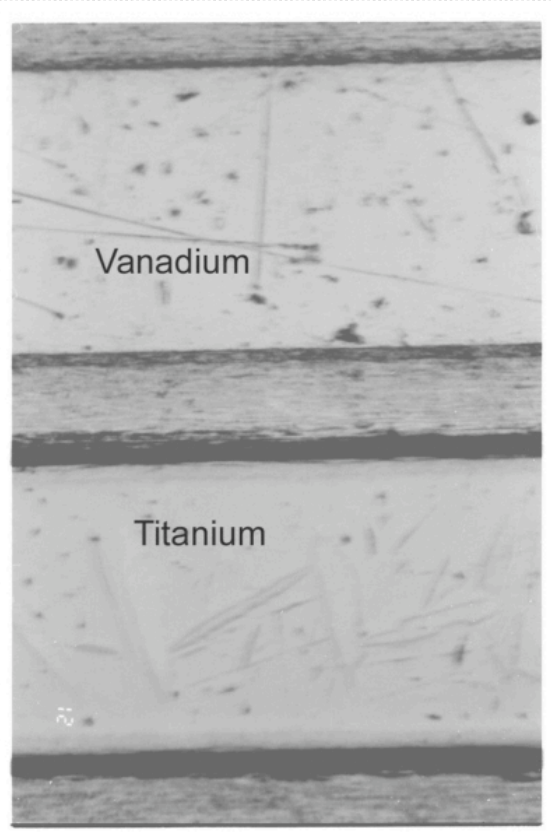
- Test article designed as two prototypes sharing a common face
  - One side heated with water (high flow rate)
  - One side cooled with helium
  - Bonded as single unit
- Test results were inconclusive
  - Much lower thermal resistance than predicted (0.275 K*cm^2/W)
  - Only one data point taken at high heat flux (@ 30-50% higher He flow rate)





Tungsten Diffusion Bonding Experiments

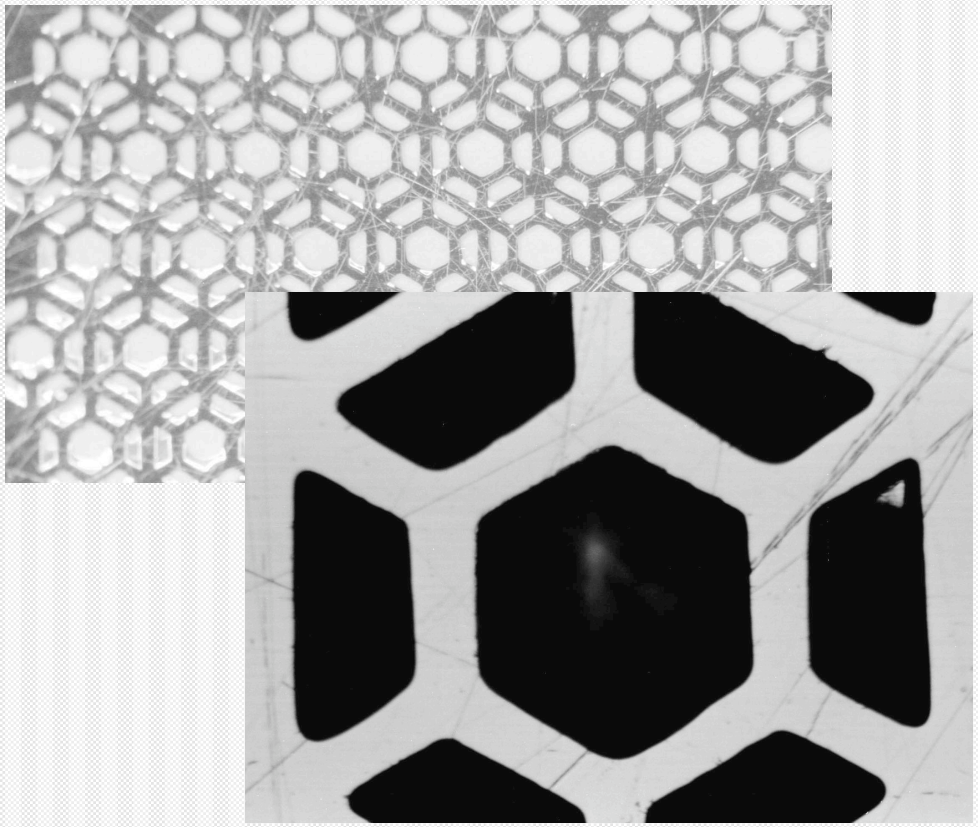
- Diffusion bonding of 0.05 mm tungsten foils was evaluated
- Three bonding aids were investigated
  - Nickel & NiB_2
  - Vanadium
  - Titanium
- Titanium was the most promising
  - Vanadium delaminated
  - Nickel caused recrystallization of the tungsten



Diffusion Bonded Test Sample

Results of Tungsten Etching Trials

- Photochemical etching trials were performed on thin tungsten foils
- Used patterns employed for the prototype
- Electrolytic etching was shown to provide clean etches without degradation of the photoresist



Hexagonal Microchannel Array Etched in 0.002” Thick Tungsten Foil

Summary of Hex-Array Concept

- Provides Affordable Microchannel-Class Cooling Over Large Areas
- Allows Use of Helium as Coolant
- Compatible with Tungsten as Armor and Heatsink Material
- Can Form Monolithic or Functionally Graded Structures